A Study Of Dynamic Response Of Circular Water tank With Baffle Walls

Kavita Chaudhari[1], S L Bhilare[2], G R Patil[3]

[1] *PG Student, Department of Civil Engineering, (Structures), JSPM's RSCOE, Tathawade Pune, Maharashtra*
[2] *Professor, Department of Civil Engineering, (Structures), JSPM's RSCOE, Tathawade Pune, Maharashtra*
[3] *Associate Professor, Department of Civil Engineering, (Structures), JSPM's RSCOE, Tathawade Pune, Maharashtra*
---***---

Abstract - *This paper, enlights the effect of providing baffle walls in circular water tanks to suppress or minimize the effect of sloshing and hence studying the dynamic response of circular water tank for earthquake loading. As the water tanks are very important life line structures which needs to be survived after any type of disaster. To increase the performance of the circular water tanks, baffle walls can be effectively provided. In this work two types of baffle walls i.e. vertical and ring baffle wall is considered. The numerical study is done with the help of finite element model of tank-fluid system using ANSYS software. Also, Dynamic analysis is carried out for models with and without baffle wall and the results are plotted.*

***Key Words**: Circular tank; Sloshing; Hydrodynamic; Baffle, CFD*

1. INTRODUCTION

Sloshing is characterized by the oscillation of the unrestrained free surface of the liquid in a partially filled container due to external excitation. Slosh refers to the movement of one liquid inside another object under motion. The frequently causing main reasons of failure of water tanks are,

1) Sloshing effects of liquid and flexibility of container wall is not considered properly while evaluating the seismic forces on tanks.
2) It is documented that tanks are less ductile and contain low energy absorbing capacity as well as redundancy as compared to the conventional building system and other structures which is not considered properly.
3) Improper design and wrong selection of supporting system and under estimated or over estimated strength of the tank.

Baffles are commonly used as effective means of suppressing the magnitudes of fluid slosh, apart from enhancing the integrity of the tank structure.

Two types of baffles can therefore be distinguished:

(i)   Solid baffles, used as obstructions perpendicular to the flow to change the direction of the flow.
(ii)   Perforated baffles, used to break up the main jet into a more uniform current over a larger area without the deliberate intention to change the direction.

2. OBJECTIVE AND FORMULATION

In this paper, effect of various types of baffle walls in circular water tank to suppress the sloshing is analysed.   The methodology of this work is as under:

*   Carrying over necessary literature survey.
*   Water tank parameters such as geometry (circular), material of tank (Concrete / steel), type of tank (resting on ground) is selected.
*   Based on expected capacity of tank, size of tank i.e. diameter and height of tank is to be selected.
*   Type of baffle wall i.e. material, placement of baffle wall shall be selected.
*   Compute natural frequency, time period and respective mode shapes of circular water tank with and without baffle wall.
*   Modeling of circular tank with and without baffle wall and its analysis using ANSYS
*   Comparing numerical analysis results of various types of baffle wall with tank without baffle wall. And comparing variation in total deformation, normal stress, shear stress and bending stress due to use of baffle wall
*   Checking design parameters such as effect of opening, height of baffle wall.

3. CODAL PROVISIONS

IS 1893:2002-Part 2 is used for calculation of dynamic response of water tank. Along with hydrostatic forces, hydrodynamic forces exerted by liquid on tank wall, shall also be incorporated in the analysis for the water tanks. Spring-mass model is used to estimate this hydrodynamic force.

If a liquid tank vibrates along with liquid, the liquid exerts both impulsive as well as convective hydrodynamic pressures on tank wall and base of the tank, together with the hydrostatic pressure. To incorporate this effect of hydrodynamic pressure, in the analysis, tank is idealized by corresponding spring- mass model, which includes the effect of wall of tank and liquid interface. The various parameters of this model depends upon geometry and flexibility of the tank.
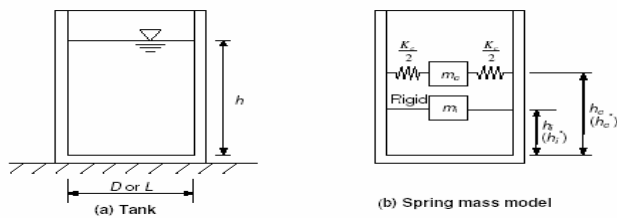
Fig-1 : Spring Mass Model for Circular Tank
(Ref: IS 1893 Part II)

For circular water tanks, parameters mi, mc, hi, hc etc can be obtained as per graphs given in IS -1893 Part II. As shown above, in spring mass model of tank for circular tanks, hi is the height where resultant of impulsive hydrodynamic pressure on wall is situated from bottom of the tank wall. Whereas hi* is the height, at which point, the resultant impulsive pressure on wall and the base is positioned from the tank wall bottom. Consequently, if, base pressure effect is not considered, mi, impulsive mass of liquid will act at a height of hi from internal face of tank and if base pressure effect is considered, mi* will act at a height hi* from internal face of tank.

In the same way, hc is the height, where, resultant convective pressure on wall is located from bottom of the tank wall, while, hc* is the height at which point, resultant of convective pressure on wall and base is located. Heights hc, hc* are described in Figures. Hence, the value of hi and hc shall be used to calculate moment due to hydrodynamic pressure at the bottom of the tank wall.
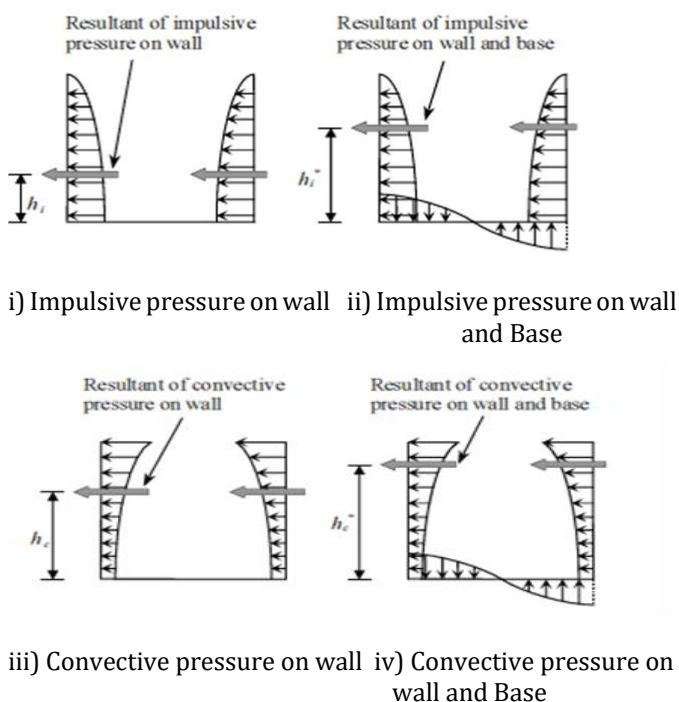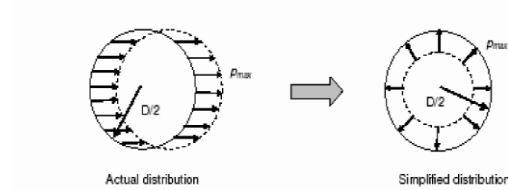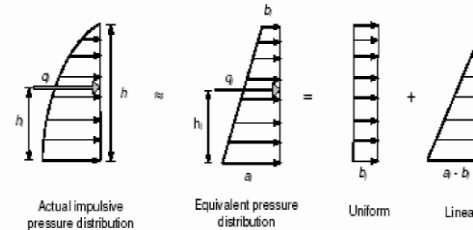

i) Impulsive pressure on wall   ii) Impulsive pressure on wall and Base

iii) Convective pressure on wall iv) Convective pressure on wall and Base

Fig- 2: Qualitative description of hydrodynamic pressure on tank wall and base

(i) Simplified pressure-distribution in circumferential direction on tank wall

(ii) Equivalent impulsive pressure linear-distribution along wall height for
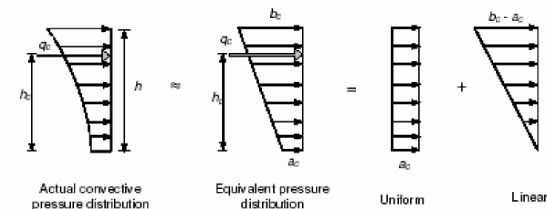
iii) Equivalent convective pressure linear-distribution along wall height for

Fig- 3. Hydrodynamic pressure distribution for wall analysis (Ref: IS 1893 (Part2) Doc No. CED 39(7231))

4. PROBLEM STATEMENT

A circular reinforced concrete water tank without roof of capacity 3600m3 is resting on ground. Tank is situated above strata of soft soil in seismic zone IV. Analyze the tank for seismic loads. Various parameters considered for tank are as follows:

- **Properties of tank**

Inside Dia of Tank	14640mm
Height of tank	21920mm
Tank Wall Thickness	300mm
Base Slab Thickness	400mm
Grade of concrete	30
Volume of water	3600m3
Mass of Water (M)	3600000Kg

For this Tank CFD analysis is carried out using ANSYS.16. Results are as follows

5. FEA MODEL ANSYS.16

Using FEA tool following models are analyzed
Model 1: Circular water tank without baffle wall
Model 2: Circular water tank with horizontal ring baffle wall
Model 3: Circular water tank with 1/3rd height vertical baffle wall
Model 4: Circular water tank with 1/2 height vertical baffle wall
Model 5: Circular water tank with 2/3rd height vertical baffle wall
Model 6: Circular water tank with 1/3rd height vertical baffle wall with single circular opening
Model 7: Circular water tank with 1/3rd height vertical baffle wall with multiple circular openings
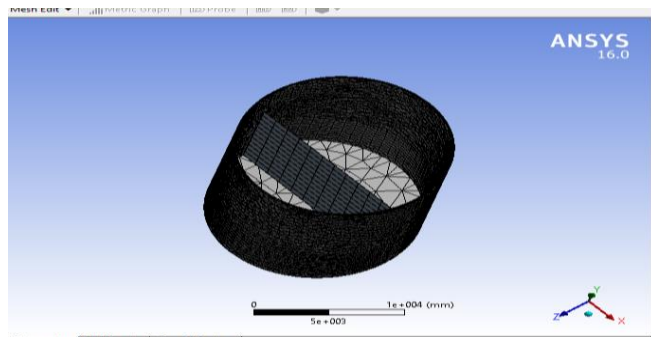
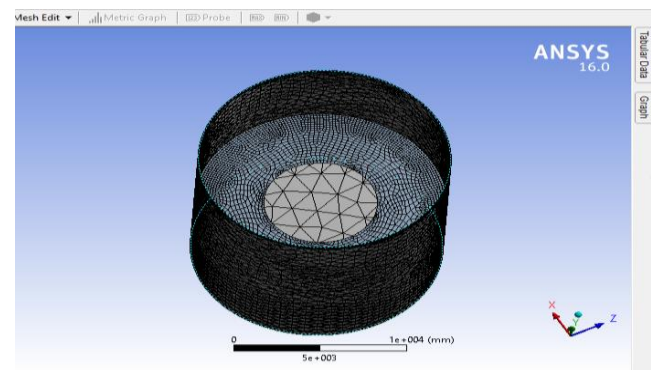**Fig- 4:** Finite element Mesh of vertical baffle wall

Fig-5: Finite element Mesh of ring baffle wall

5.1 Effect due to provision of Baffle wall

Table -1: Values of Total Deformation for CFD Analysis

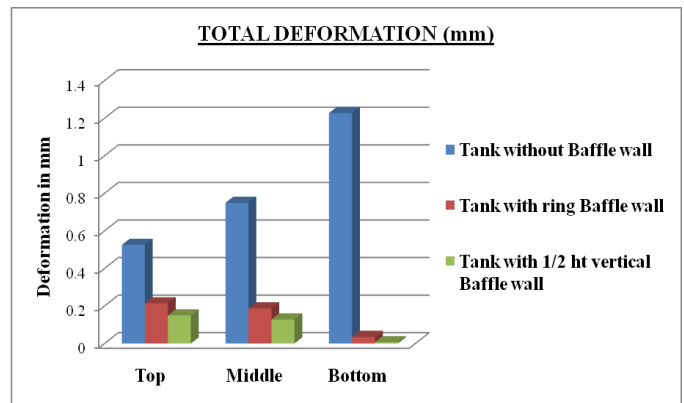| Total Deformation			
	Tank without Baffle wall	Tank with ring Baffle wall	Tank with vertical Baffle wall
Top	0.52509	0.21356	0.14972
Middle	0.74914	0.18721	0.12751
Bottom	1.2271	0.034984	0.0070307

Chart-1: Graphical representation of Total deformation for CFD Analysis

Table- 2: Values of Normal stress for CFD Analysis

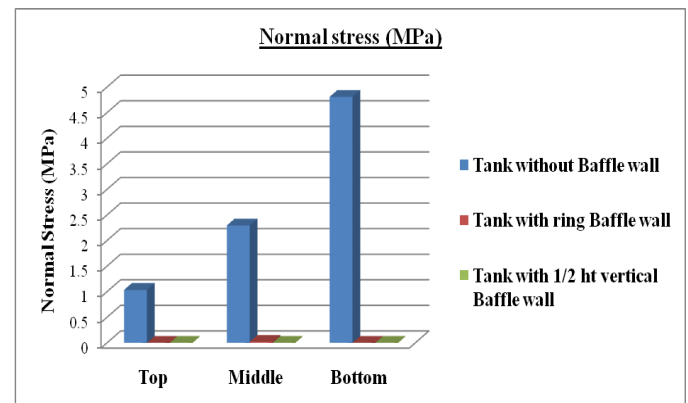| Normal stress			
	Tank without Baffle wall	Tank with ring Baffle wall	Tank with vertical Baffle wall
Top	1.0363	0.00040889	0.00039134
Middle	2.2957	0.020844	0.00086345
Bottom	4.8095	0.0013897	0.00025673

Chart-2: Graphical representation of Normal stress for CFD Analysis

Table-3: Values of Shear stress for CFD Analysis

Shear stress			
	Tank without Baffle wall	Tank with ring Baffle wall	Tank with vertical Baffle wall
Top	0.00385	0.0003841	0.0002601
Middle	0.002589	0.0023979	0.0015305
Bottom	0.0368	0.001706	0.0012665
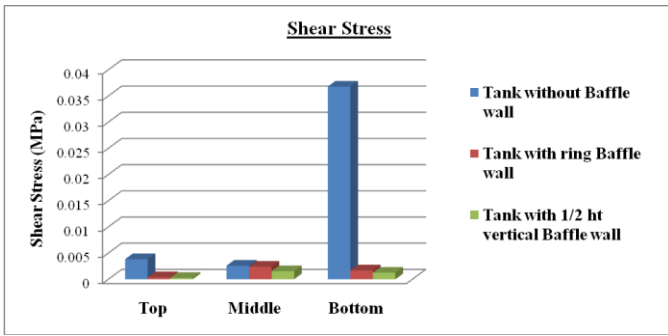
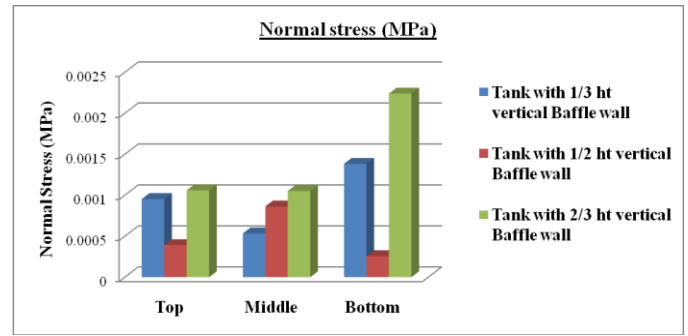**Chart-3:** Graphical representation of Total deformation for CFD Analysis

5.2 Effect of variation in height of baffle wall:

Further, to study the effect of height of baffle wall three models with different height of baffle wall are prepared and analyzed. The results are as shown below:

Table-4: Values of Total Deformation for CFD Analysis for height variation

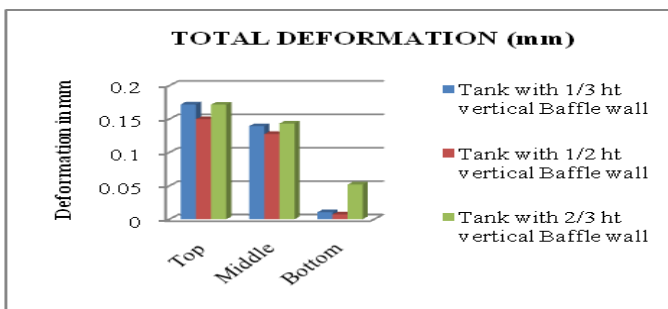| Total deformation			
	Tank with 1/3 ht vertical Baffle wall	Tank with 1/2 ht vertical Baffle wall	Tank with 2/3 ht vertical Baffle wall
Top	0.17177	0.14972	0.17151
Middle	0.13927	0.12751	0.14328
Bottom	0.0104	0.0070307	0.05184

Chart-4: Graphical representation of Total deformation for height variation

Table-5: Values of Normal stress for CFD Analysis for height variation

Normal Stress			
	Tank with 1/3 ht vertical Baffle wall	Tank with 1/2 ht vertical Baffle wall	Tank with 2/3 ht vertical Baffle wall
Top	0.0009532	0.0003913	0.0010595
Middle	0.00053362	0.00086345	0.0010516
Bottom	0.0013821	0.00025673	0.0022397

Chart-5: Graphical representation of Normal stress for height variation

Table-6: Values of shear stress for CFD Analysis for height variation

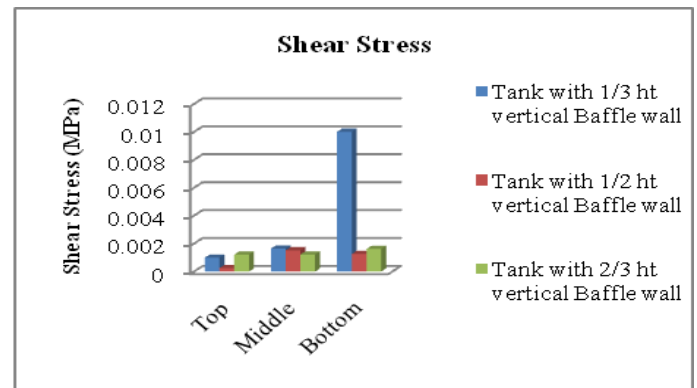| Shear Stress			
	Tank with 1/3 ht vertical Baffle wall	Tank with 1/2 ht vertical Baffle wall	Tank with 2/3 ht vertical Baffle wall
Top	0.001003	0.0002601	0.0012197
Middle	0.0016503	0.0015305	0.0012177
Bottom	0.010016	0.0012665	0.0016261

Chart-6: Graphical representation of Shear stress for height variation

From above three graphs, it can be seen that half height baffle wall tank has lesser values of deformation and stresses as compared to other three models.

5.2 Effect of opening in vertical baffle wall:

Afterwards, the effect of opening is analysed for models with centrally equally spaced 3m diameter single circular and multiple (03 Nos) circular openings at vertical baffle wall. The geometry of the water tank with single circular and multiple circular i.e. 03 Nos openings is as shown below:
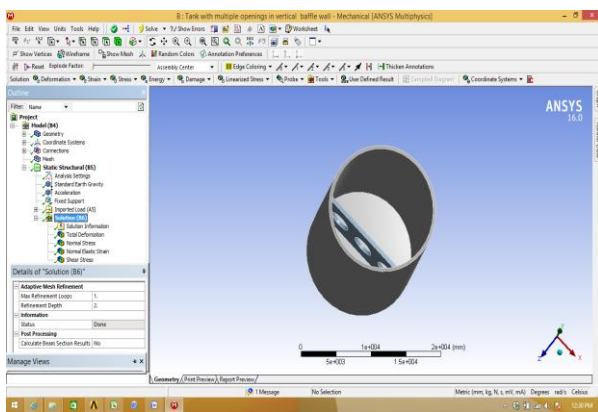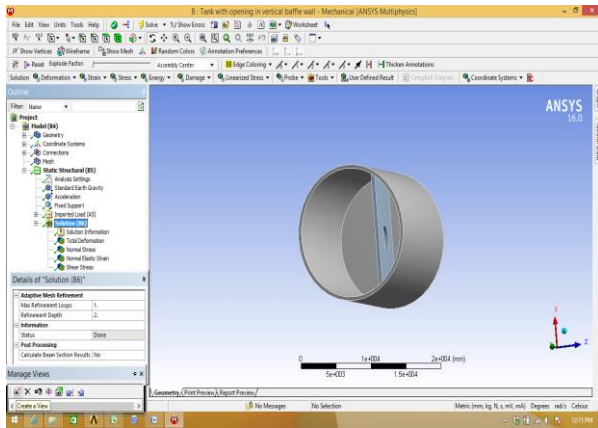
Fig-6: Geometry of baffle wall with openings for CFD Analysis

Table-7: Values of Total Deformation for CFD Analysis for effect of opening

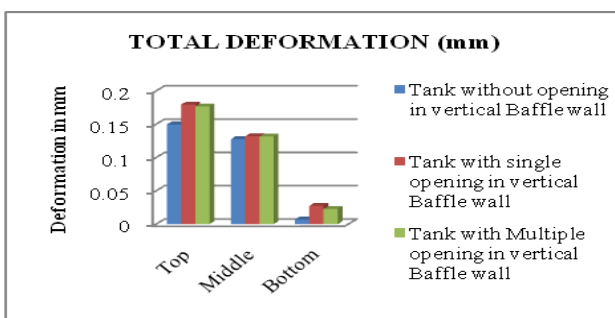| Total deformation			
	Tank without opening in vertical Baffle wall	Tank with single opening in vertical Baffle wall	Tank with Multiple opening in vertical Baffle wall
Top	0.14972	0.17932	0.17662
Middle	0.12751	0.13175	0.13137
Bottom	0.0070307	0.02725	0.022559

Chart-7: Graphical representation of Total deformation for effect of opening

Table-8: Values of Normal stress for CFD Analysis for height variation

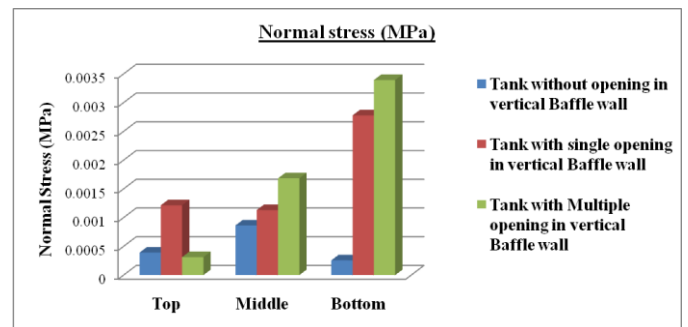| Normal Stress			
	Tank without opening in vertical Baffle wall	Tank with single opening in vertical Baffle wall	Tank with Multiple opening in vertical Baffle wall
Top	0.0009532	0.0012148	0.0003133
Middle	0.00053362	0.0011314	0.001684
Bottom	0.0013821	0.0027791	0.0033944

Chart-8: Graphical representation of Normal stress for effect of opening

Table-9: Values of Shear stress for CFD Analysis for effect of opening

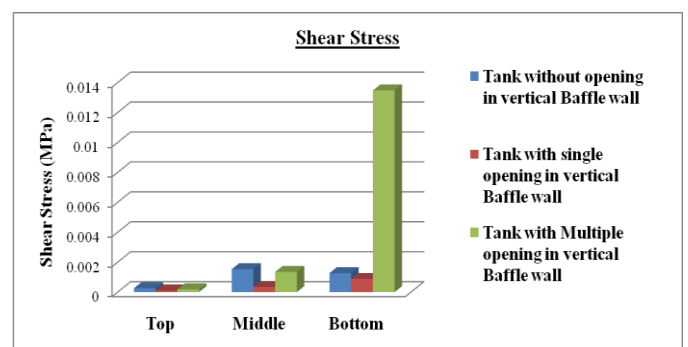| Shear Stress			
	Tank without opening in vertical Baffle wall	Tank with single opening in vertical Baffle wall	Tank with Multiple opening in vertical Baffle wall
Top	0.001003	0.00011461	0.00018297
Middle	0.0016503	0.00033877	0.001353
Bottom	0.010016	0.00087828	0.013474

Chart-9: Graphical representation of Shear stress for effect of opening

6. CONCLUSIONS

Numerical study on circular water tank with and without baffle wall is carried out for hydrodynamic forces and past earthquake data. From all the above results and graphical representations, it can be seen that baffled tank increases the performance of circular water tank. From the trends of the numerical results of the present study, the following conclusions may be drawn:

➢ Total deformation of tank reduces in both vertical and ring baffled tanks than tank without baffle wall.

➢ Normal stress, shear stress and Equivalent stresses at various locations of tank are lesser in tank with baffle wall than tank without baffle wall by more than 60%.

➢ From comparison of height of baffle wall, it is concluded that one half height baffle wall has less deformation by about 32% and stresses are less by 60 to 80% than baffle wall of one third or two third height of tank.

➢ From comparison of effect of opening in baffle wall, it is concluded that provision of opening is not recommended as it results in swirl effect and increases stresses

ACKNOWLEDGEMENT

REFERENCES

[1] O.R Jaiswall, Shraddha Kulkarni and Pavan Pathak (2008) : A Study On Sloshing Frequencies of Fluid-Tank System: The 14th world Conference on Earthquake Engineering October 12-17, 2008, Beijing, China

[2] J.H. Jung et al (2012) : "Effect of the vertical baffle height on the liquid sloshing in a three-dimensional rectangular tank " : Ocean engineering,2012.

[3] Xue-lian Zheng, Xian-sheng Li, Yuan-yuanRen, Yuning Wang, and Jie Ma (2013): Effects of Transverse Baffle Design on Reducing Liquid Sloshing in Partially Filled Tank Vehicles Hindawi Publishing Corporation Mathematical Problems in Engineering Volume 2013, Article ID 130570

[4] H. L. Tiwari (2013), Analysis Of Baffle Wall Gap in The Design of Stilling Basin Model : International Journal of Civil Engineering and Technology (IJCIET), ISSN 0976 – 6308 (Print), ISSN 0976 – 6316 (Online) Volume 4, Issue 4, July-August (2013), © IAEME 66

[5] Prasad Dhumal, Mr. S. R. Suryawanshi (2016) : A Study of Effect of Baffle Wall on Dynamic Response of Elevated Water Tank using Ansys 16 IJIRST – International Journal for Innovative Research in Science & Technology| Volume 3 | Issue 01 | June 2016ISSN (online): 2349-6010 www.ijirst.org

[6] I.H Cho et.al (2016) : Sloshing reduction in a swaying rectangular tank by an horizontal porous baffle : Science direct : Ocean Engineering 138 (2017) 23–34

[7] IS 1893 Part II: Doc No. CED 39 (7231)

[8] www.endurocomposites.com/products/water-wastewater-products/baffle-wall